Collection and Treatment of Flowback and Produced Waters from Hydraulic Fracturing

Edwin Pinero
Veolia Water North America
The Issue

- Oil and gas production using enhanced techniques is NOT new
- Hydraulic fracturing is NOT new
- Oil and gas production using hydraulic fracturing IS NEW in some geographies
- Public interest, awareness, and concern is high
- Many myths and misconceptions
- The use of water and impact to water resources is a major concern
Industry Challenges – Flow Back and Produced Water

- Increasing Transportation Cost
- Storage Cost – Frac Tanks, Impoundments, Tankage
- Flowback/Produced Water Processing
- Solid Waste Management
- Managing Total Cost
- Regulations Tightening
- Disposal Outlets are decreasing
- Best Available Technology

Goals: Reduce, Reuse, Recycle
Managing water and wastewater services for public authorities and industry

Designing technological solutions and building and managing the facilities and systems required to deliver these services

Construction, rehabilitation and maintenance of networks and associated infrastructure

2009 Revenue
$18.1 billion

95,000 employees

Drinking water services to 95 million people

Wastewater services to 68 million people

Facilities managed +5,260 water +3,220 wastewater

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The View from the Water Company

- **Quantity**- Need to address the supply issue- where is it coming from and is there enough?

- **Cross contamination**- how secure are the aquifers?
  - Well construction and expertise of drillers

- **Quality**- what is being put in the water, how well is it being treated, and what is it doing to the water resources?
Collection and treatment Issues

- Decentralized sources
- Rates variable, highest for short period during development
- No infrastructure in new areas
- Transport and Discharge issues - footprint
- Challenging chemistry relative to effluent discharge options and disposal of solids
Fracking Fluid

- Over 90% water
- 9% sand
- Approximately 1% of “everything else”
  - Everything else can be salts, ethylene glycol, sodium, potassium carbonate, and a suite of proprietary mixes
- Primary quality concern: salts and solids
- Primary quantity concern: it takes a LOT of water!...but does it really compared to other uses of water? The golf course example
Flowback

- Early on, mainly fracking fluid and formation water
- Over time, more formation water
- Quality issues, decreasing frack chemicals and increasing percentage of formation chemistry
- Formation chemistry- salts, metals, NORM, organic compounds, etc.
How Much are we talking about?
An Example

Marcellus Shale

- Approx. 5,000,000 gallons of water used to frac each well
- Approx. 1,000,000 gallons of water flows back over a 30 day period – (Flow Back Water)
- After the well is put into production - The remaining 4,000,000 gallons plus any other source water is produced over the life of the well (Produced Water) – 10 bbls (420gal)/day/well

Solutions

- Modular approaches- package and mobile treatment plants
- Centralized treatment in local areas
- Reuse of treated water
- Highly efficient treatment (fast, cheap, low discharge, maximum water recovery)
Treatment Levels

- **Level 1 – Minimal Treatment -** **Reuse**
  - Total Suspended Solids Removal – TSS – Physical Chemical Treatment

- **Level 2 – Specific Ion Removal + TSS Removal -** **Reuse**
  - Target removal of ions like Iron, Calcium, Barium, Strontium, Metals – Physical Chemical Treatment

- **Level 3 – Meet Discharge limits for** **Disposal**
  - Must remove Total Dissolved Solids (all ions)
  - Typical TDS levels in the Marcellus 120,000 ppm
  - Discharge limit <500 ppm
  - Typically Accomplished through application of thermal treatment when TDS levels >45,000 ppm – (Evaporation/Crystallization Technology)
  - <45,000 ppm membrane technology is applicable
Total Water Management

- Includes
  - Collection
  - Transportation
  - Treatment
  - Mixing
  - Storage

- Reusing 100% of the flow back water and the majority of produced water

80% Fresh Water
Rivers, ponds, Muni

20% - Flow Back & Produced
Water treatment on site

Frac water delivered to specification
Field Experience – *TSS and Iron Removal*

**Case Study: Service Based**

- On-going treatment in Marcellus with a major exploration company
Field Experience – **TSS and Iron Removal**

Case Study: Current Treatment Results - Solids

- **Challenge – Eliminate Hazardous Waste**
  - Pass the paint filter test
  - Pass Toxicity Characteristic Leaching Procedure - TCLP

- **Significant Cost Savings (Non-Haz vs Haz)**
Shale Gas Plays, Lower 48 States

Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009
Field Experience – ion removal

Case Study: Mobile Water System for Frac Reuse

- Enables Flowback Reuse
  - Flow Rate up to 10,000 bpd
  - Proven MULTIFLO™ Softening Technology
  - Associated Chemical Feed Skid
  - Fully Integrated System

- Removes Scale-Formers

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Influent</th>
<th>Effluent</th>
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</thead>
<tbody>
<tr>
<td>Calcium Hardness, ppm as CaCO₃</td>
<td>8,000 – 40,000</td>
<td>&lt;50.0</td>
</tr>
<tr>
<td>Magnesium Hardness, ppm as CaCO₃</td>
<td>1,000 – 4,000</td>
<td>&lt;50.0</td>
</tr>
<tr>
<td>Iron, ppm</td>
<td>25 – 200</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Manganese, ppm</td>
<td>5 – 10</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Barium, ppm</td>
<td>500 – 16,500</td>
<td>&lt;10.0</td>
</tr>
<tr>
<td>Strontium</td>
<td>800 – 5,000</td>
<td>&lt;10.0</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS), ppm</td>
<td>100 – 1,000</td>
<td>&lt;30.0</td>
</tr>
</tbody>
</table>
Field Experience – TDS Removal
San Ardo Facility
Principle

Produced Water

de-oiling and solids filtration

- surface discharge 50,000 bpd
- once through steam generation 70,000 bpd
What is OPUS® II Technology?

- Optimized Pretreatment Unique Separation Process
- An innovative technology for sustainable reuse of industrial wastewater
- A Patented Technology covered by US Patent No. 5,250,185
- Key process advantage: high system water recovery rates
So what does all of this mean?

- Flowback and produced water is manageable

- There are various options to address differences in geography, chemistry, and producer requirements

- There is much activity in the development of technology and process to further improve the situation

- No one wants the water issue to be a barrier